Performance evaluation of Magnetic circuit for M.R. Fluid Damper using F.E.M.

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Abstract : **The primary purpose of this study is to evaluate and understand the performance of the Magnetic -Rheological (MR) damper. It is known that its performance depends upon the magnetic and hydraulic circuit design. These dampers are generally used to control the vibrations in various applications. This work deals with design of an MR damper for which mathematical model is developed. A finite element model is built to analyze and investigate the performance of 2-D axi-symmetric MR damper. Various configurations of damper piston with different number of turns and pole lengths are simulated. Further, the piston ends of the selected configuration are modified and investigated. The input current to the coil and the piston velocity are varied to evaluate the resulting change in magnetic Field Intensity (H) and damping Force. The simulation results of the various configurations of damper show that the performance of filleted piston ends is superior to that of other configurations for the same magnitude of coil current and piston velocity.**

*Index terms***: Magneto-rheological (MR) fluid, MR damper, Magnetic flux density, Magnetic field intensity.**

I. INTRODUCTION

During the past decade, many researchers have shown keen interest in the development of damper which utilize magneto- rheological fluid (MRF). Magneto- rheological (MR) fluid is a fascinating material, composed of micro-sized magnetic particles suspended in a liquid, such as hydrocarbon oil or silicone oil. The rheological properties of MR fluid are rapidly and reversibly altered when an external magnetic field is applied. When current is passed through the coil, the suspended particles in the MR fluid become magnetized and align themselves like chains in the direction of the magnetic field. The formation of these particle chains restricts the movement of the MR fluid, thereby increasing its yield stress. The saturation current for the standard MR fluid, 132 DG is 2.0A as provided by Lords Corporation. Designs that take advantage of MR fluids are potentially simpler and more reliable than conventional electromechanical devices. Maher Yahya Salloom and Samad [1] designed an MR valve for which simulation was carried out by magnetic finite element software (FEMMR). Sodeyama and Suzuki et.al [2] have developed and tested an MR damper which provided maximum damping force.of 300kN. H.yoshioka, j.c. Ramallo et.al.[3]constructed and tested a base isolated two-degree freedom building model subjected to simulated ground motion which is effective for both far- field and near- field earthquake

excitations. Jansen and Dyke [4] evaluated the performance of number of semi active control algorithms that are used with multiple MR dampers. Spencer and Dyke et.al. [5] Proposed a new model to effectively as semi-active control device for producing a controllable damping force portray the nonlinear behavior of MR fluid damper. N. Seetharamaih and khan et al. [6] design and developed the prototype of small capacity MR damper. Lai and W.H Liao [7] have found that MR fluid damper can be used. Henri Gavin Jesse Hoagg et.al [8] have made a comparison between ER and MR devices in the context of electrical power requirements. Zekeriya parlak Tahsin and Ismail,Calli [9] designed an optimization method that was carried out for the objectives of target damper force and maximum magnetic flux density of an MR damper.

The main objective of this paper is to evaluate the different models of MR damper using ANSYS software.

NOMENCLATURE

A_p : piston cross section area
d   : spool length
$d_{cyl}, d_{sh,}$: diameters of the cylinder and shaft
              respectively
e   : house thickness
H   : fluid viscosity in the absence of the
              field, C
I   : current
L, g, W : length, gap and width of the flow
              channel between the fixed poles
N   : number of turns
Q   : volumetric flow rate
V_p : velocity of the piston
τ : shear stress,
τ_y : field-dependent yield stress,
ΔP_η : viscous component of pressure drop
ΔP_τ : yield stress component of pressure
              drop

$\dot{\gamma}$: Fluid shear rate

1P   : one stage coil with plain ends
1C   : one stage coil with chamfered ends
1F   : one stage coil with filleted ends
MFD   : Magnetic Flux density

II. METHODOLOGY

The damper design is done based on the fact that mechanical energy required for yielding of MR fluid increases with increase in applied magnetic field intensity. In the presence of magnetic field, the MR fluid follows Bingham's Plastic flow model, given by the equation

$$\tau = \eta\, \dot{\gamma} + \tau_y(H) \qquad \tau > \tau_y$$

The above equation is used to design a device which works on the basis of MR fluid. The total pressure drop in the damper is evaluated by summing the viscous component and yield stress component which is approximated as

$$\Delta P = \frac{12\eta Q L}{g^3 W} + \frac{C\tau_y L}{g} \quad , \quad \text{where}$$

$$\eta = 0.0006\ \dot{\gamma}^{-0.6091}$$

$$Q = A_p V_p$$

$$A_p = \frac{\pi\left[(d_{cyl} - 2g)^2 - d_{sh}^{\,2}\right]}{4}$$

$$W = \pi(d_{cyl} - g)$$

the value of the parameter, C ranges from a minimum of 2 (for $\Delta P\tau\ \Delta P\eta$ less than ~1) to a maximum of 3 (for $\Delta P_\tau / \Delta P_\eta$ greater than ~100).

In order to calculate the change in pressure on either side of the piston within the cylinder, yield stress is required which is obtained from the graph of yield stress v_s magnetic field intensity provided by Lord corporation for MR fluid - 132 DG.

III. FINITE ELEMENT MODELING OF MR DAMPER

The proposed MR damper consists of a piston over which coil is wound and an annular gap of 0.4 mm is maintained between the piston and its housing .The piston is made up of mild steel due to its high relative permeability. The various dimensional features of the damper are shown in Figure 1.

In the present research work, various configurations of damper piston with different number of turns and pole lengths are considered to analyze a 2D axisymmetric MR damper. The procedure adopted for the analysis of these models is given in Figure 2. Further, the piston ends of the selected configuration are modified and investigated. In these later models, different shapes of piston with plain, chamfered and filleted ends are considered as shown in Figures 3, 4 and 5 while keeping the dimensions of the piston, number of turns of the coil and annular gap constant.

These models are analyzed to study the variation of magnetic field intensity and magnetic flux density with respect to the current supplied. The current is varied from 0.2A to 2A and analysis is carried out ANSYS ^{R} 11 software. The variation of 2D flux lines, magnetic flux density and magnetic field
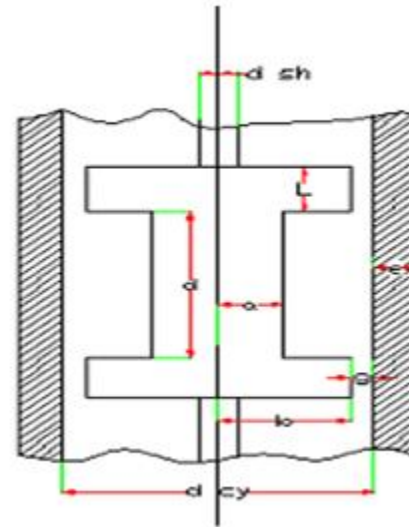

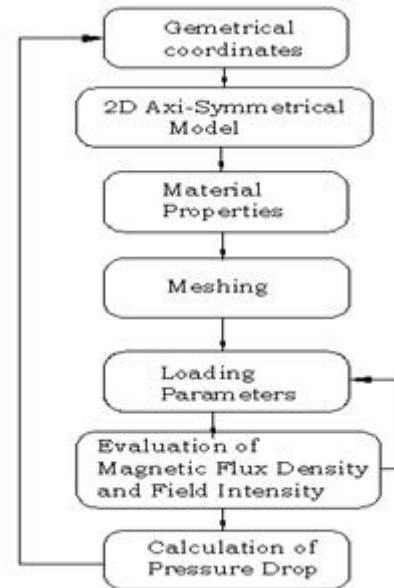Figure 1. Schematic of MR damper

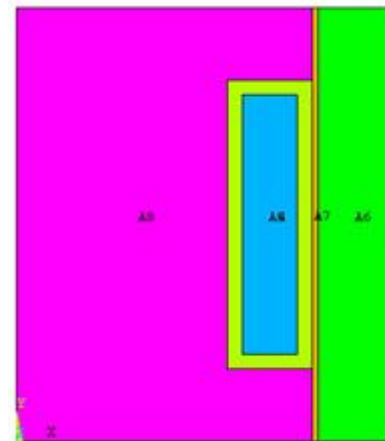Figure 2. Steps for calculation of Pressure drop

Figure 3. Piston with plain ends

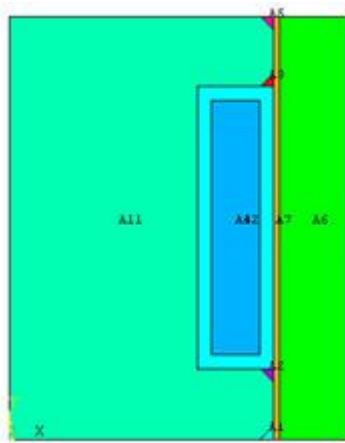intensity for the different models at 2 amperes are shown in Figure 6 to Figure 10.
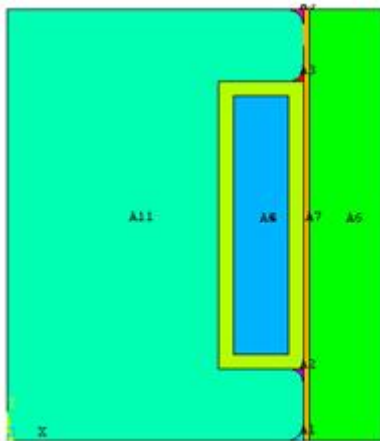
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Figure 4. Piston with chamfered ends
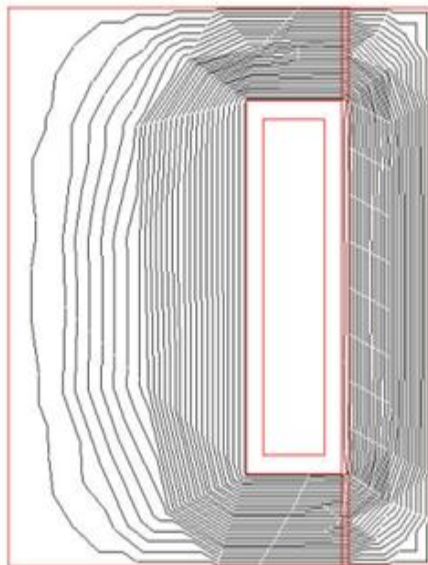

Figure 5. Piston with filleted ends

Figure 6. Flux lines around the coil

Figure 7. Magnetic flux density vectors

Figure 8. Magnetic field intensity

IV. SIMULATION RESULTS AND ANALYSIS

The number of turns of the plain end models are increased and decreased by 5% and 10% of the original model. These variations are s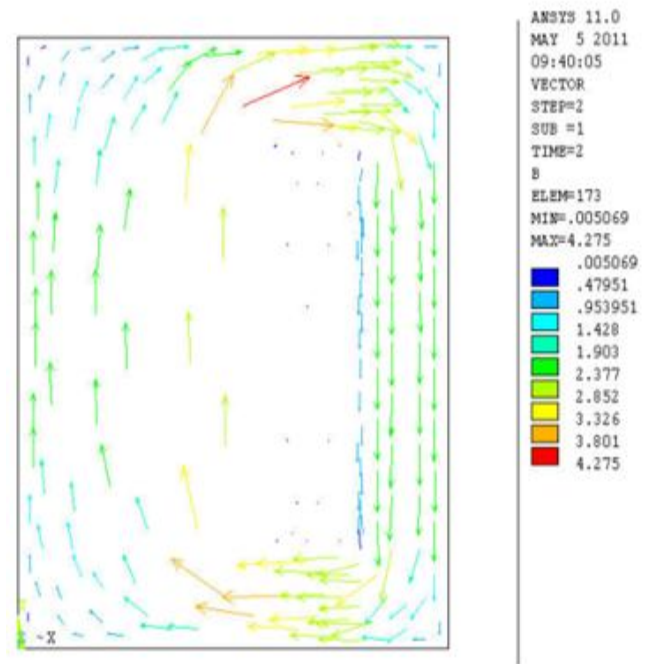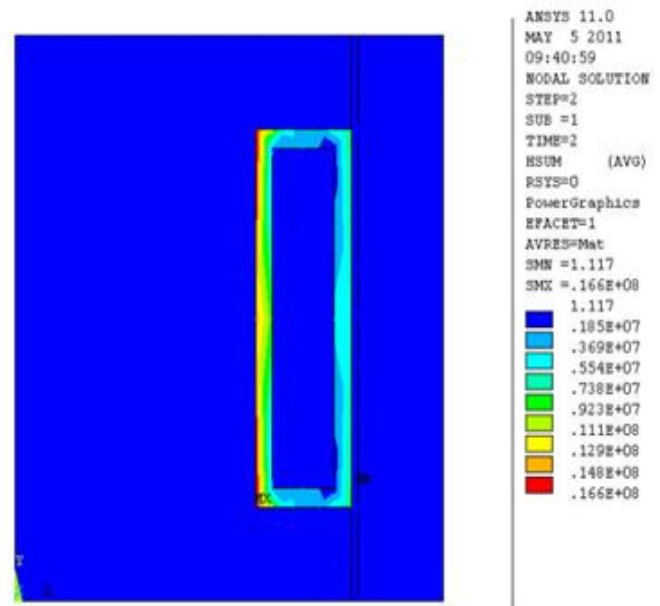imulated and it is observed that the damping force decreases irrespective of change in the number of turns as shown in Figure 11.

The total pole length of the plain end models is increased and decreased by 5% and 10% of the original model. The simulation results depicted in Figure 12 show a remarkable decrease in the damping force across the piston.

From the above simulation results, the optimum number of turns and total pole length of the damper is considered for further analysis. The performance of the plain end model is now compared with two different piston models having chamfered and filleted ends. The simulation results of damping force with respect to magnetic field intensity and flow rate for 2 amp current and constant gap of 0.4 mm for various models are shown in Figure 13 and Figure 14.

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TIME=2
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RSYS=0
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EFACET=1
AVRES=Mat
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SMX =3.297
     .004297
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     1.834
     2.2
     2.566
     2.932
     3.297
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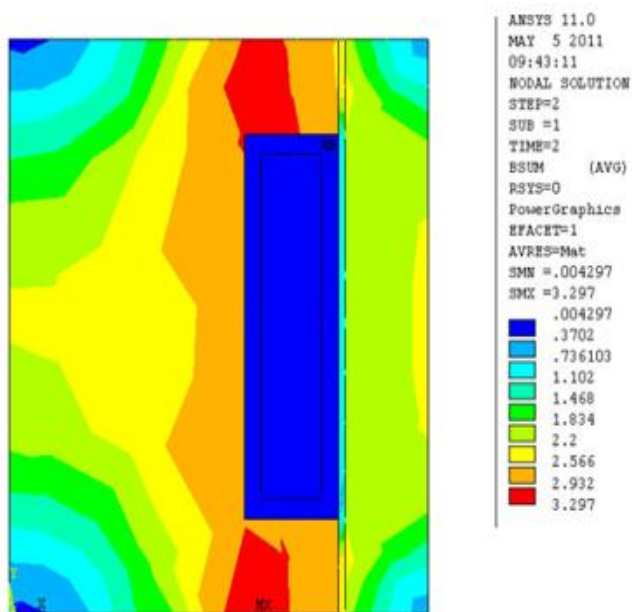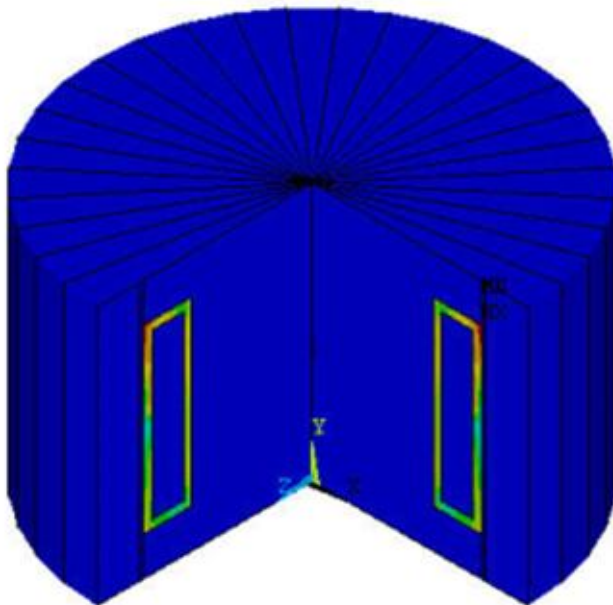
Figure 9. Magnetic flux density vector sum

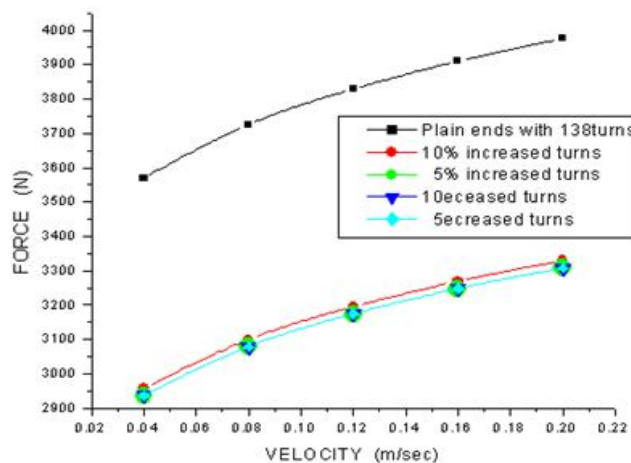Figure 10. 3-D model of MR fluid Damper

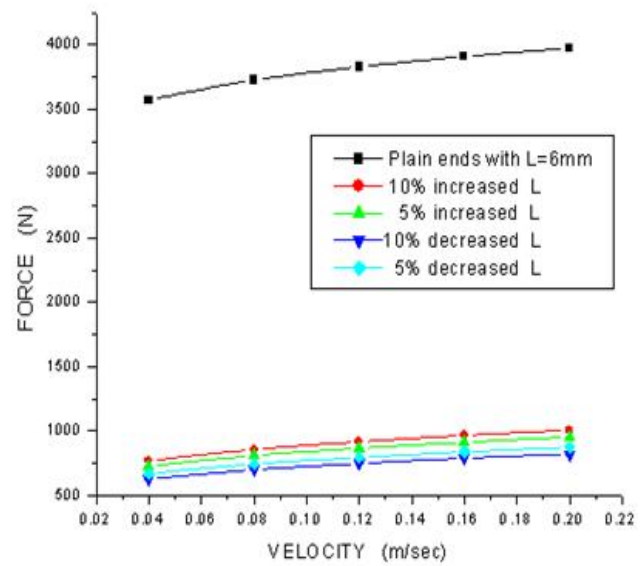Figure 11. Force Vs Velocity for different number of coil turns

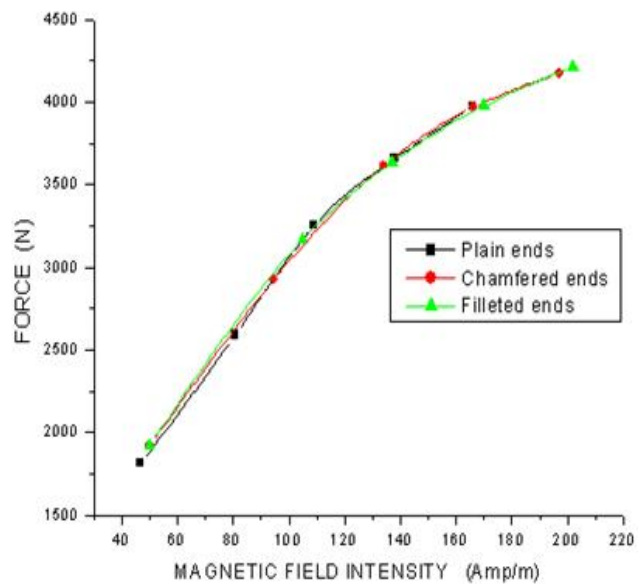Figure 12. Force Vs Velocity for different pole lengths

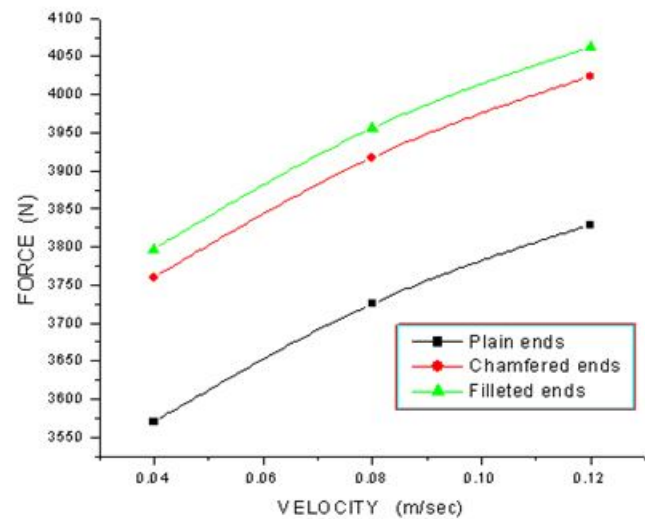Figure 13. Force Vs Magnetic Field Intensity for different piston ends

Figure 14. Force Vs Velocity for different Piston ends

4

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It is observed that as coil current increases the magnetic field intensity increases, thereby increasing the damping force. Maximum damping force is observed in case of filleted piston end model. Figure 14 shows that the damping force increases with increase of velocity of MR fluid. The maximum damping force with respect to velocity is also found in case of filleted piston end model.

V. CONCLUSION

It is observed that increase or decrease in the number of turns of coils and total pole length did not improve the performance of the damper in terms of damping force. Further simulation results of the three different models of MR damper with plain, chamfered and filleted ends showed that filleted ends model gave optimum damping force with respect to magnetic field intensity as well as velocity. The filleted ends assisted the formation of dense magnetic flux lines thereby increasing the flux density. This implies that higher load can be carried by the damper even with a small capacity.

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